

Contribution to the study of narrow low mass hadronic structures

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New data are presented, concerning narrow exotic structures in mesons, baryons and dibaryons. The sequence of narrow baryons is quite well described starting from the sequence of narrow mesons. In the same way, the sequence of narrow dibaryons is rather well described starting from the sequence of narrow baryons. Lastly it is shown that the masses of these narrow hadronic structures lie on straight line Regge-like trajectories.

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I. INTRODUCTION

This paper presents new data concerning narrow hadronic structures in several species, namely in mesons, baryons, and dibaryons. Many data were already published, and therefore are not repeated here, the corresponding papers are only quoted. Some new data, not published up to now, are shown.

It is also desirable to look at possible similitudes between mass spectra of the three hadronic species. Indeed, if such connection exist, it will give a strong argument in favor of the genuine existence of these structures, which therefore could not be associated to accidental statistical effects.

II. MESONS

A. Short summary of previously published data

A paper, recently published [1], shows evidence for narrow and weakly excited mesonic structures, with masses below and just above the pion mass ($M=139.56$ MeV). These data are mainly missing mass precise spectra of the $pp \rightarrow ppX$ reaction, studied at SPES3 (Saturne) and also selected results from COSY, Celsius, MAMI, and JLAB Hall A, Hall B, and Hall C. The statistical confidence is often large. In some cases, this confidence is not large, but several structures at approximately the same masses are observed. These masses are $M=62$ MeV, 80 MeV, 100 MeV, 181 MeV, 198 MeV, 215 MeV, 227.5 MeV, and 235 MeV, although the last one may be uncertain, since determined by only three data, and being located

at the limit of the spectra.

Several papers [2] [3] show, some time ago, evidence for narrow mesonic structures at masses larger than the pion mass. These masses are: $M=310$ MeV, 350 MeV, 430 MeV, (495) MeV, 555 MeV, 588 MeV, 608 MeV, 647 MeV, 681 MeV, 700 MeV, and 750 MeV.

B. New data from the $\gamma p \rightarrow p\pi^+\pi^-$ reaction studied at MAMI

The helicity dependence for the $\gamma p \rightarrow p\pi^+\pi^-$ reaction was studied with the detector DAPHNE at the tagged photon beam facility at the MAMI accelerator in Mainz [4]. The cross sections were assembled into six ranges of photon incident energy, with photon energy interval widths of 50 MeV, altogether between 500 MeV and 800 MeV. The spectra were compared by the authors [4] to the predictions of the Fix-Arenhövel model [5] (FA). These spectra, versus the two-pion invariant mass $M_{\pi\pi}$, show some small structures well outside the statistical uncertainties.

An attempt is done here, to look how better agreement can be achieved, with the assumption to add small narrow mesonic structures to the Fix-Arenhövel model, at the same masses as those extracted from previous papers. Since the model gives in some cases larger cross sections than the measured ones, we have arbitrarily renormalized the model values by 0.5 , in order to suppress all negative differences. Fig. 1 and fig. 2 show the cross sections for the six incident photon energies. The masses of the gaussians are $M_{\pi\pi}=310$ MeV, 350 MeV, 390 MeV, 430 MeV, 495 MeV, and 555 MeV. A gaussian at $M=390$ MeV is introduced here although not extracted before. The gaussians widths are fixed to $\sigma=20$ MeV. Fig. 3, and fig. 4 show the cross sections for the spin- $1/2$ state for the $p\pi^\pm$

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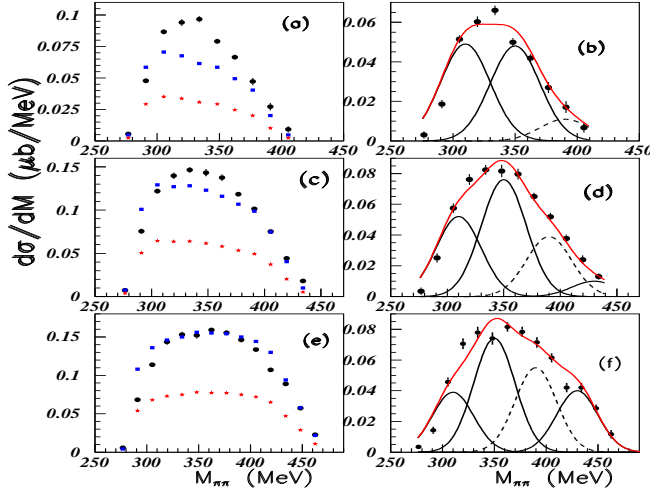


FIG. 1: Tentative reanalysis of the $\gamma p \rightarrow p \pi^+ \pi^-$ reaction studied at MAMI [4]. Inserts (a), (b), and (c) show the data (full circles), the values of the FA model [5] (full squares), and the same after renormalization (stars). Inserts (b), (d), and (f) show the differences and their analysis into fixed mass gaussians. Inserts (a) and (b) correspond to $500 \leq T_\gamma \leq 550$ MeV, inserts (c) and (d) correspond to $550 \leq T_\gamma \leq 600$ MeV, and inserts (e) and (f) correspond to $600 \leq T_\gamma \leq 650$ MeV.

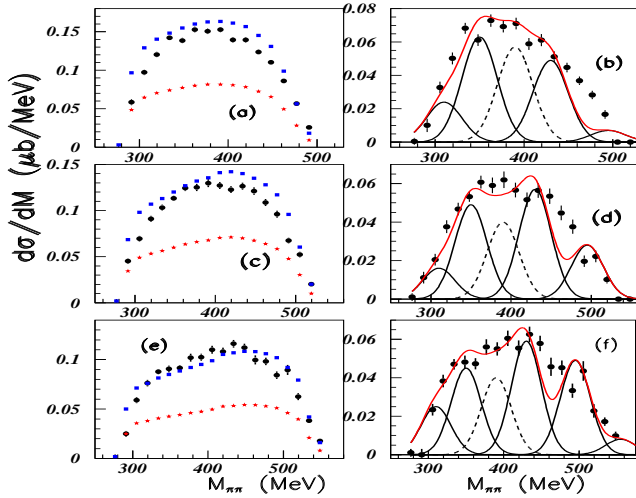


FIG. 2: Same caption as for Fig. 1, except that inserts (a) and (b) correspond to $650 \leq T_\gamma \leq 700$ MeV, inserts (c) and (d) correspond to $700 \leq T_\gamma \leq 750$ MeV, and inserts (e) and (f) correspond to $750 \leq T_\gamma \leq 800$ MeV.

system. Fig. 5 and fig. 6 show the cross sections for the spin-3/2 state for the $p\pi^\pm$ system. The same masses are used for all six figs., but in figs. 3, 4, 5, and 6 a larger width ($\sigma=24$ MeV) is used for gaussians, since the experimental binning is larger. Fig. 7 shows the integral of the narrow structure cross sections. We observe that each insert, which corresponds to a specific narrow mesonic structure mass, show a regular shape, smoothly varying with the incident photon energy. We observe that

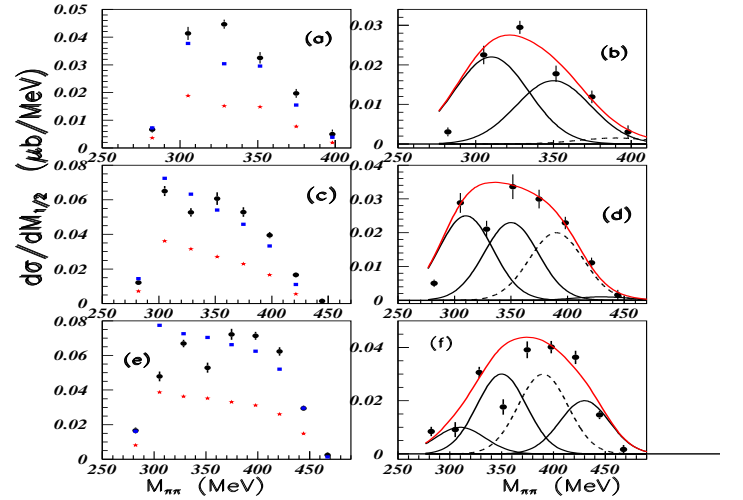


FIG. 3: Same caption as for fig. 1, except that here the cross sections are for the spin-1/2 state for the $p\pi^\pm$ system

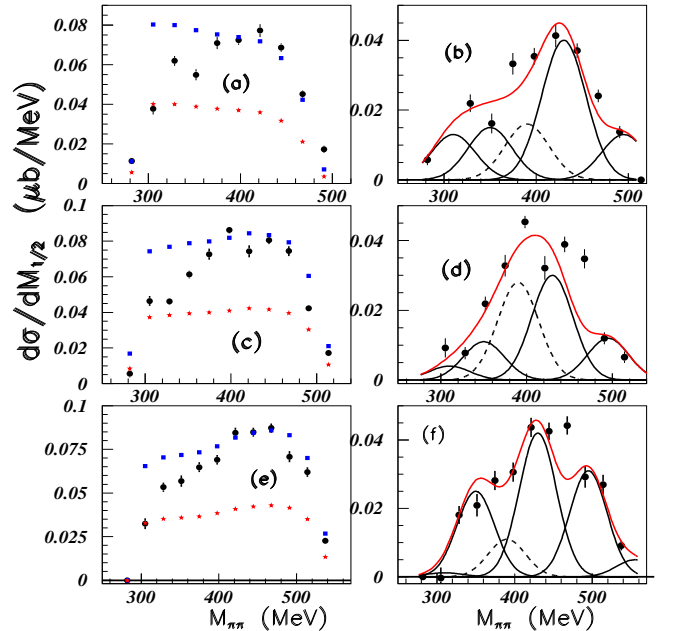


FIG. 4: Same caption as for fig. 2, except that here the cross sections are for the spin-1/2 state for the $p\pi^\pm$ system

the $M=310$ MeV structure is mainly influenced by the $\Delta(3/2, 3/2)(1232)$ resonance. The last insert (f) shows, the display of the broad PDG baryonic resonances arbitrarily normalized. We observe that the shapes of all narrow mesonic increasing mass structures, are "influenced" by increasing PDG baryonic resonance masses. However such property cannot help us to suggest a possible isospin or spin, to the narrow mesonic structures.

C. The old $pp \rightarrow dX$ data

The $pp \rightarrow dX$ reaction was studied in Birmingham [6] long time ago. In order to study the phase shifts of the $T=0$ $\pi - \pi$ interaction, the authors compare the corresponding cross sections with those obtained using a deuteron target. They extracted the spectrum of the $T=0 \rightarrow d2\pi$ which was plotted versus p_d , the detected deuteron momentum (their fig. 4). This spectrum was read, and reported in fig. 8(a) versus the missing mass of the reaction. We observe the two branches of the kinematics at both sides of the maximum missing mass $M_X=430$ MeV. Indeed the incident proton energy $T_p=991$ MeV, and the deuteron lab. scattering angle $\theta_d=4.2^\circ$ allow a maximum missing mass $M_X=430$ MeV. In fig. 8(a) we reported below the data, their calculation of the enhanced phase space incorporating a value of $1.0 \hbar/mc$ for the $\pi\pi$ S-wave scattering length, renormalized by 0.5 in order to be lower than the data in all spectrum range.

Fig. 8(b) shows the data subtracted from this phase space. Clear structures are extracted, which are already seen in insert (a). The real shape of the space space is therefore not important, provided it does not present narrow structures. Table I shows that the masses of the extracted peaks reproduced fairly well the narrow structure masses extracted previously from the SPES3 data. All structures are extracted with gaussians with an unique width $\sigma=23$ MeV. Fig. 9 shows the corresponding results for $T=1$ isospin state ($pp \rightarrow dX$ reaction). Here, except a possible very small structure close to $M_X=430$ MeV, no clear isovectorial structure can be extracted. This agrees with the Bose-Einstein statistics. Indeed these low mass pionic structures have $l=0$ orbital momenta, and the total two-pion isospin must be even. This agrees also with the spin and isospin values predicted for these states from

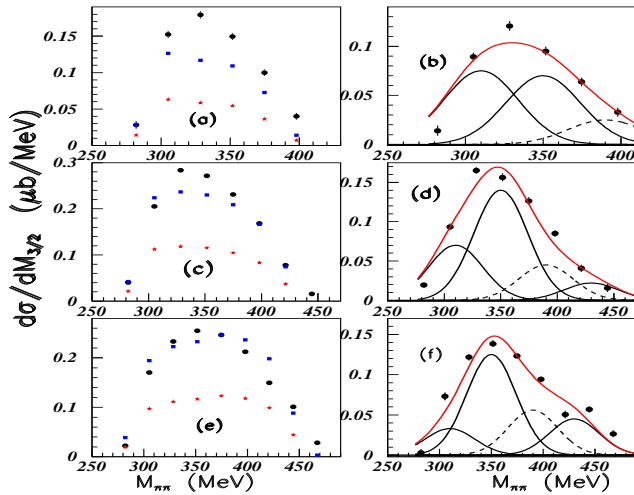


FIG. 5: Same caption as for fig. 1, except that here the cross sections are for the spin-3/2 state for the $p\pi^\pm$ system.

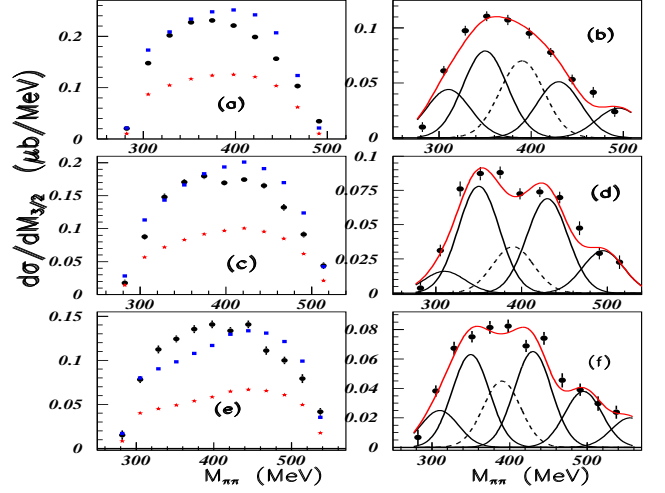


FIG. 6: Same caption as for fig. 2, except that here the cross sections are for the spin-3/2 state for the $p\pi^\pm$ system.

the SPES3 data [2].

D. Discussion

Several other data, sometimes not very precise, exist, which exhibit the presence of structures not belonging to classical PDG mesons. For example, the missing mass of the $pp \rightarrow ppX$ reaction, measured at Argonne National Laboratory [7]. In their fig. 3(b) a clear peak is observed

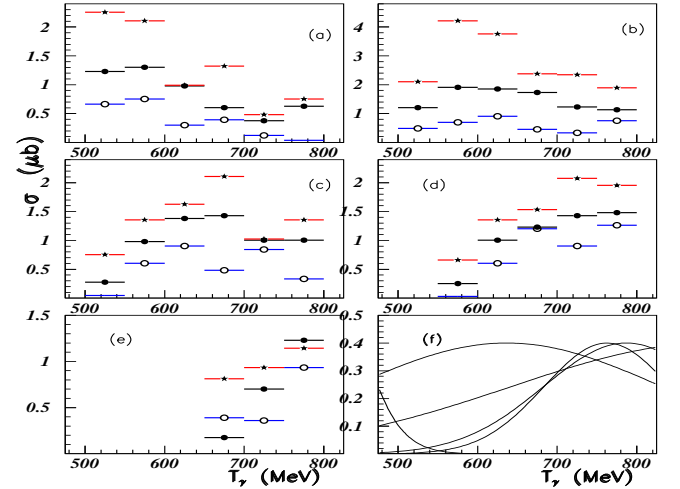


FIG. 7: Total cross sections of the mesonic narrow structures. The five inserts: (a), (b), (c), (d), and (e), correspond respectively to the following mesonic structure masses: $M=310, 350, 390, 430$, and 495 MeV. The full circles show the cross-section, the stars show the cross section for spin-3/2 state for the $p\pi^\pm$ system., and the empty circles show the same for spin-1/2 states. The last insert (f), shows the display of the broad PDG baryonic resonances arbitrarily normalized.

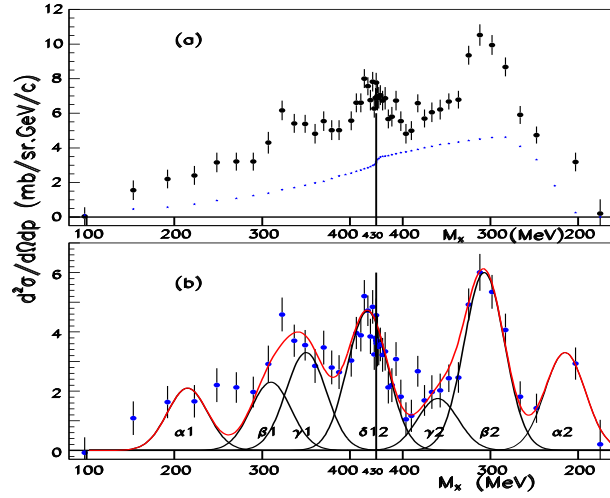


FIG. 8: Spectrum of the $T=0$ $pn \rightarrow dX$ reaction [6]. Insert (a) shows the data plotted versus the missing mass M_X . Insert (b) shows the narrow mesonic structures extracted from the data minus phase space (see text).

α			β			γ			δ		
1	2	spes3	1	2	spes3	1	2	spes3	12	spes3	
215	215	215	310	307	310	350	360	350	420	430	

TABLE I: Masses (in MeV) of the forward (1) and backward (2) pionic missing mass branches, from the $pN \rightarrow dX$ reaction [6]. In comparison the masses extracted from SPES3 experiments are also given.

between the π^0 and the η mesons. An additional argument in favor of these structures can be put forward, if the corresponding masses display a continuous behaviour when displayed on Regge trajectories.

It is accepted that all hadrons are Reggeons, that is lie on Regge trajectories. This was studied in [1] where it was shown that three straight lines describe the Regge-like trajectories. Fig. 10 reproduces this result.

$$NJ = a + b.M^2 \quad [1]$$

We name them Regge-like, since the integer values in the ordinate - NJ - represent an unknown quantum number. The first line lies below one pion mass, the second line lies between one and two pion masses, and the third line lies above two pion masses. We get very large slopes "b" (in GeV^{-2}) - see table II, when the corresponding value from the broad PDG mesons is close to $b=0.877$ [8]. In previous works showing evidence for narrow hadronic structures, their masses were computed using a mass formula for two clusters of quarks at the ends of a stretched bag derived some years ago in terms of color magnetic interactions [9]:

$$M = M_0 + M_1[i_1(i_1 + 1) + i_2(i_2 + 1) + (1/3)]$$

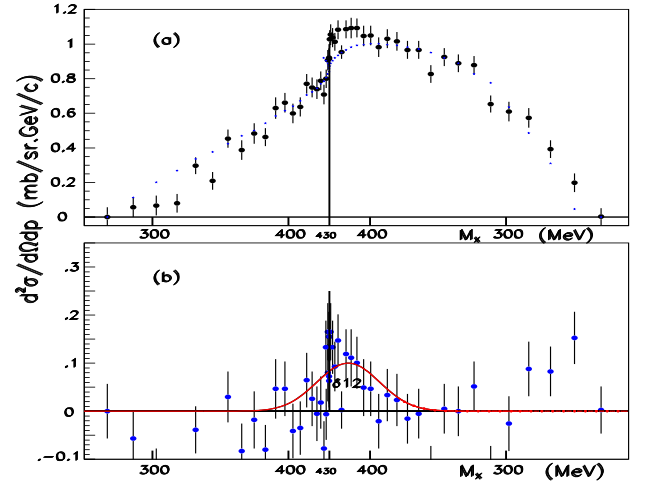


FIG. 9: Same caption as for fig. 8, except that here the cross sections are for the isospin $T=1$.

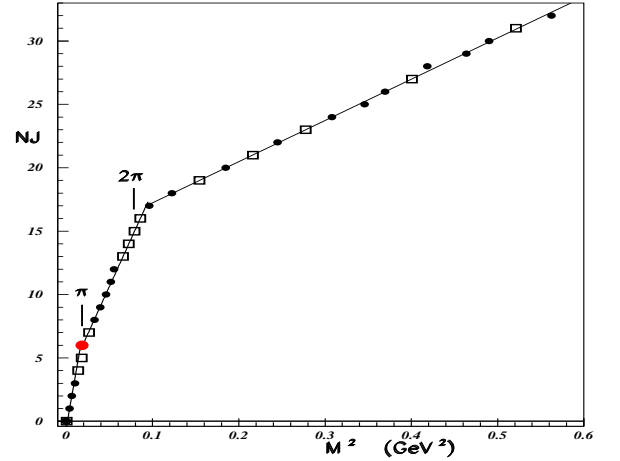


FIG. 10: Regge-like trajectory of all narrow structure mesonic masses observed in this work and in [2] [3].

$$(s_1(s_1 + 1) + s_2(s_2 + 1)) \quad [2]$$

where M_0 and M_1 are parameters deduced in [9] from mesonic and baryonic mass spectra, and $i_1(i_2)$, $s_1(s_2)$ are isospin, spin of the first (second) quark cluster. Although it is not proven that these structures are a manifestation of colored quark clusters, we have considered such assumption and shown that the use of such mass formula, with the condition to be phenomenological, allows to reproduce the experimentally observed masses with only two adjustable parameters. Notice that the formula give rise to degeneracy in spin and isospin.

Now, using the Regge-like trajectory slopes, we are able to suggest the masses of both clusters. We use a simple relation, derived long time ago by Barut [10] [11], which relates (with several assumptions) the slope "b" of the Regge-like trajectories with the masses of two interacting clusters:

$$\lambda = b^{-1} = 8m_1m_2/137 \quad [3]$$

where m_1 and m_2 are the masses of both clusters. Using the assumption that the mass of the constituent quarks $m_q = m_{\bar{q}}$ is close to 310 MeV, the previous formula allows us to determine the clusters through the calculation of the corresponding quark mass. The results of such calculations for mesons are shown in table II. The clusters giving a mass close to $M=310$ MeV are favoured.

We observe that the $(q\bar{q})$ -($q\bar{q}$) clusters are the most appropriate for the present analysis. For the larger masses studied here, the $q^3 - \bar{q}^3$ clusters may also be appropriate. For mesons, we have made the assumption that the clusters are $(q\bar{q})^2$. The $q - \bar{q}$ configurations are not introduced, since there is no room for such configurations in the field of narrow exotic mesonic structures. For these low mass mesonic structures, we have $l=0$ orbital momenta between both quark clusters, and then all levels have positive parities.

It was previously shown, in [2] [3], that the experimentally observed narrow mesonic structure masses were satisfactorily reproduced above two pion threshold mass, by calculation, using mass formula [1], with $M_0=310$ MeV and $M_1=30$ MeV. Table II shows that above two-pion threshold mass, where the Regge-like trajectory slope equals 32.5 GeV^{-2} , the quark cluster configurations should be first $(q\bar{q})$ -($q\bar{q}$), and for larger masses $q^3 - \bar{q}^3$. This was indeed done in [2], where above $M=470$ MeV the masses were calculated using $q^3 - \bar{q}^3$ configurations, and above $M=620$ MeV using $q^4 - \bar{q}^4$ configurations [3].

Here, below two-pion mass, because the large value of the Regge-like trajectory slope, the $(q\bar{q})$ -($q\bar{q}$) configurations must be used. This is done in fig. 11. There is no obligation to use the same values of both parameters, as those used in the mass range above two pion threshold. We keep however the same value of $M_1=30$ MeV, and adjust only $M_0=60$ MeV, in order to get the masses shown in fig. 11.

experi.	calc. $q^2 - \bar{q}^2$
----- 235	
----- 228	
----- 215	----- 220 (0,1,2),(0,1,2)
----- 198	----- 200 (1),(0,1,2)
----- 181	----- 180 (0),(0,1,2,)
	----- 160 (0,1,2),(1)
	----- 140 (1),(1)
	----- 120 (0),(1)
----- 100	----- 100 (0,1,2),(0)
----- 80	----- 80 (1),(0)
----- 62	----- 60 (0),(0)
	(Spin),(Isospin)

FIG. 11: Experimental and calculated masses of narrow low mass mesonic structures. The quantum numbers for calculated levels are (S),(I).

b (GeV^{-2})	$(q\bar{q} - q\bar{q})$	$(q^3 - \bar{q}^3)$	M_{min}	M_{max}
390	104.8	69.8	0	135
149.7	169.1	112.7	235	300
32.5	362.9	242	300	760

TABLE II: Constituent quark mass, for different clusters supposed to describe the mesonic narrow structures, derived from the Barut's equation [10]. M_{min} and M_{max} give, in MeV, the mass range of each trajectory.

If we omit the three predicted structures at $M=120$ MeV, 140 MeV, and 160 MeV, we observe the agreement between experimental and calculated masses. The calculated mass at $M=140$ MeV cannot be the pion, since the spin here is $J=1$. More, the large pion peak excitation is clearly related to $q\bar{q}$ configurations, These three predicted small structures at $M=120$ MeV, 140 MeV, and 160 MeV, could only be looked for in dedicated experiments with very good resolution, therefore at low incident energy and forward angle missing mass experiments.

III. BARYONS

A. Previously shown narrow baryonic structures data

Narrow baryonic structures were observed, first in the mass range $1.0 \leq M \leq 1.4$ GeV studied at SPES3 (Saturne) with use of the $pp \rightarrow p\pi^+X$ reactions [12]. This study was followed by the introduction of the data from the $pp \rightarrow ppX$ reaction [13] and then confirmed by a careful scrutiny of different cross-sections obtained as well with incident hadrons as with incident leptons. The extracted data were reported in several papers, corresponding to the following ranges: $1.47 \leq M \leq 1.68$ GeV [14], $1.72 \leq M \leq 1.79$ GeV [15]. The masses in the mass range $1.0 \leq M \leq 1.14$ GeV are: $M=1.004, 1044, 1094, 1136, 1173, 1249, 1277, 1339$, and 1384 MeV. In the mass range $1.46 \leq M \leq 1.68$ GeV, they are: $M=1479, 1505, 1517, 1533, 1542, 1554, 1564, 1577, 1601, 1622, 1639, 1659$, and 1669 MeV. In the mass range $1.72 \leq M \leq 1.79$ GeV, they are: $M=1747$ and 1772 MeV.

B. New data from the missing mass of the $pp \rightarrow p\pi^+X$ reaction studied at SPES3 (Saturne)

The low mass range $M_N \leq M \leq 1.0$ GeV was also studied, but only preliminary results [16] were shown up to now.

Therefore the results in this low $M_N \leq M \leq 1.0$ GeV mass range are presented here. Figs. 12, 13, and 14 show a selection of cross-sections from $pp \rightarrow p\pi^+X$ reactions studied at SPES3 (Saturne). Each fig. shows two spectra

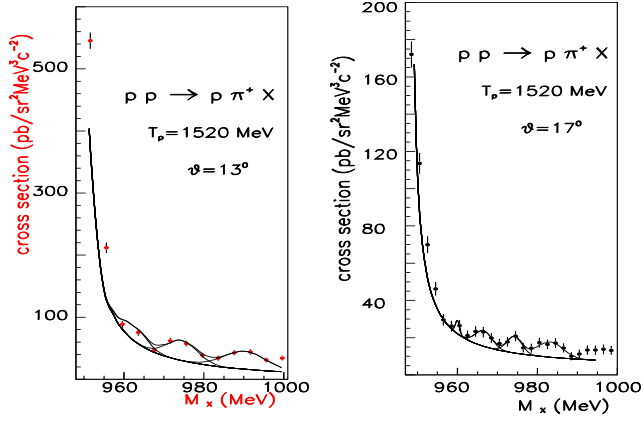


FIG. 12: Selection of two cross-sections at $T_p=1520$ MeV, showing an oscillatory pattern in the missing mass.

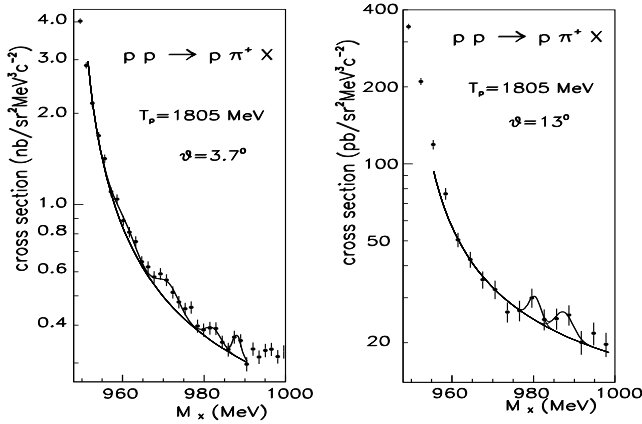


FIG. 13: Selection of two cross-sections at $T_p=1805$ MeV, showing an oscillatory pattern in the missing mass.

at the same incident energy and two different spectrometer angles. We observe "oscillatory patterns", allowing an attempt to define narrow structure masses. Here the background determination is clearly somewhat ambiguous. Several different choices can be used for background. The first one consists to draw an averaged background inside the data. Then all structures will be strongly reduced, if not disappear. However we consider as quit unlikely the situation where many spectra will exhibit an oscillatory pattern and where all these oscillations will be accidental. The second choice consists to consider these variations as physical, and to give them the same width as the experimental neutron missing mass widths which increased slowly with the spectrometer angle. Then the structures will be extracted with a higher number of standard deviation (S.D.). We choose the third - intermediate - choice and draw the background using the low data points as in Fig. 12. Although 54 peaks were extracted from all cross section spectra, only 18 were kept which had a valuable statistical significance, since they were extracted with $S.D. \geq 3$. The corresponding masses are displayed in Fig. 15. When a mass (± 1 MeV) is obtained

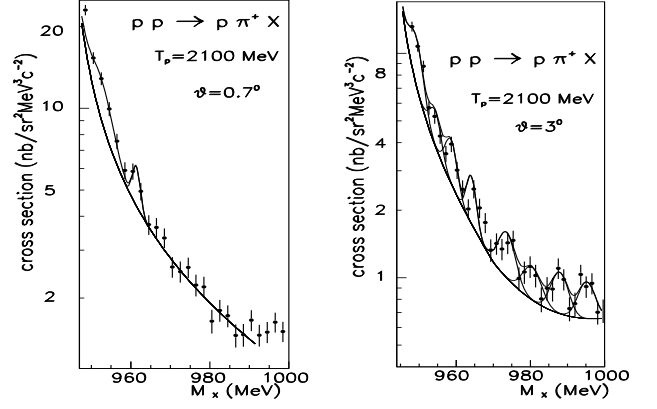


FIG. 14: Selection of two cross-sections at $T_p=2100$ MeV, showing an oscillatory pattern in the missing mass.

at least twice, it is considered as being a candidate for a new structure and an horizontal dashed range is drawn in Fig. 15. These masses are: $M=950$ MeV, 955.4 MeV, 961.5 MeV, 973 MeV, 988 MeV, and 994.8 MeV. The figure shows also the two narrow masses (at 966 MeV and 986 MeV), extracted by L.V. Filkov *et al.* from the $p d \rightarrow p p X_1$ reaction [17]. The spectra showing the

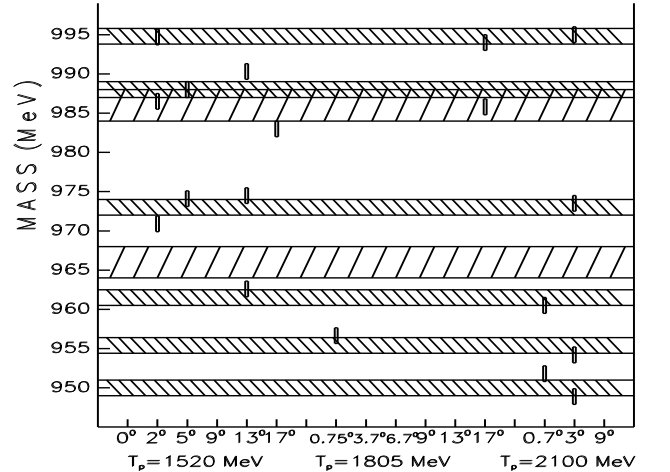


FIG. 15: Low narrow exotic baryonic masses.

narrow baryonic structures at larger masses, will not be shown here, since they were reported in previous publications [12, 13, 14, 15].

C. Discussion

As done above for mesons, the study of Regge-like trajectories of the narrow structure baryonic masses is done and shown in fig. 16. Here five different slopes are observed: the first two slopes: $b=100.4 \text{ GeV}^{-2}$ and $b=62.6 \text{ GeV}^{-2}$ in the region close to N , the third one:

$b=10.7 \text{ GeV}^{-2}$ in the mass region of the first $\Delta(3/2, 3/2)$, then the next slope $b=27.3 \text{ GeV}^{-2}$ in the mass region of several N^* , and finally $b=15.9 \text{ GeV}^{-2}$ in the next mass region where some Δ excitations predominate. Table III shows, for baryons, the constituent quark mass, depending on the quark clusters considered. We observe the different cluster predictions for all five slopes.

For baryons, in the analysis of the narrow baryonic structures at $1.0 \leq M \leq 1.4 \text{ GeV}$ [12] [13], we have made the assumption that the clusters are $(q\bar{q})^2 - q^3$ with $M_0=838.2 \text{ MeV}$ and $M_1=100.3 \text{ MeV}$. The first quantum numbers of the $(q\bar{q})^2 - q^3$ configurations are the same that those of $q - q^2$ configurations, but these last are restricted to "classical" Particle Data Group (PDG) baryons [18]. Indeed there is no room for exotic baryons within these q^3 configurations [19]. Table III shows that in the mass range $M_N \leq M \leq 1.0 \text{ GeV}$, where the slope of the Regge-like trajectory equals 10.7 GeV^{-2} such choice of configurations, namely $(q\bar{q})^2 - q^3$ is indeed predicted.

In the mass range $M_N \leq M \leq 1.0 \text{ GeV}$, following table III the masses of the narrow baryonic structures should be described with the lower mass cluster configurations. Following the previous remark, we use $q^3 - q\bar{q}$ configurations to predict the masses. The two parameters, $M_0=924 \text{ MeV}$, and $M_1=15.6 \text{ MeV}$ are adjusted in order to describe the neutron mass and the first exotic mass at 950 MeV . The other masses, possible spins and isospins, obtained with the use of formula [2], are shown in Fig. 17. We observe the good correspondance between the experimental and the calculated masses since such correspondance is obtained without any other adjustable parameter.

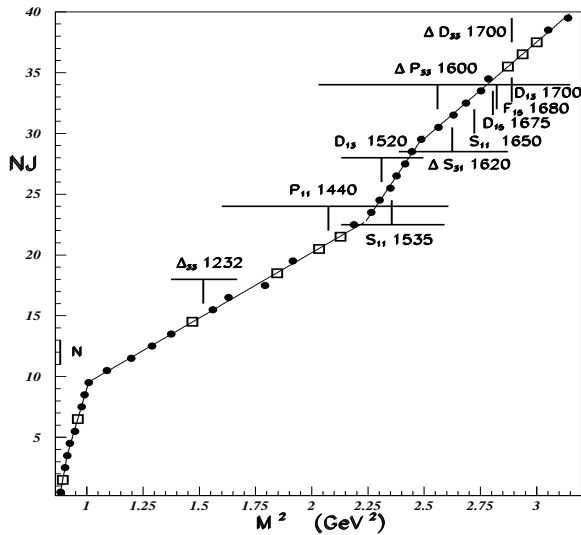


FIG. 16: Regge-like trajectory of all narrow structure baryonic masses observed in this work and in all other references quoted in the text.

Calculated (J^P) I			Experimental		
1002.	$3/2^-$	$3/2$	1004.		
996.8	$1/2^-, 3/2^-$ $1/2^-, 3/2^-, 5/2^-$	$3/2$ $1/2, 3/2$	992.6		
986.4	$1/2^-$ $3/2^-$	$3/2$ $1/2, 3/2$			
981.2	$1/2^+, 3/2^+$	$1/2, 3/2$	982		
970.8	$1/2^+$	$1/2, 3/2$	973.3		
965.6	$1/2^-, 3/2^-, 5/2^-$	$1/2$			
			961.8		
955.2	$3/2^-$	$1/2$	955.4		
950	$1/2^+, 3/2^+$	$1/2$	950.3		
939.6	$1/2^+$	$1/2$	939.6	$1/2^+$	$1/2$
Spin			Isospin		

FIG. 17: Experimental and calculated exotic baryonic masses in the range $945 \leq M \leq 1000 \text{ MeV}$.

IV. DIBARYONS

The spectrum of narrow exotic dibaryons was reported in [20], where cross-sections of experiments performed at Saturne (SPES1 and SPES3) and in different other laboratories were reanalyzed. In the mass range studied, these masses are: $M=1902, 1916, 1941, 1969, 2016, 2052, 2087, 2122, 2155, 2194, 2236$, and 2282 MeV . These masses were reproduced quite satisfactory, using the mass formula [3] for $q^4 - q^2$ quark clusters. Such agreement was obtained with $M_0=1841 \text{ MeV}$ and $M_1=52.5 \text{ MeV}$. Although the Barut's formula suggests more heavy clusters, with one or two additional $q\bar{q}$ contributions, the low calculated masses with 0 or 1 spin and isospin values are obtained indifferently of these assumptions for clusters.

Notice that the same masses and quantum numbers are obtained if $q^6 - q\bar{q}$ quark clusters will be considered. Indeed this last choice will allow additional masses only above $M=2681 \text{ MeV}$, therefore larger than those discussed here.

The corresponding Regge-like trajectory is shown in fig. 18.

V. GENERAL DISCUSSION

A. Connection between exotic meson masses and exotic baryon masses

When applying equation [2] for the calculation of exotic hadronic masses, we consider all possible spins and

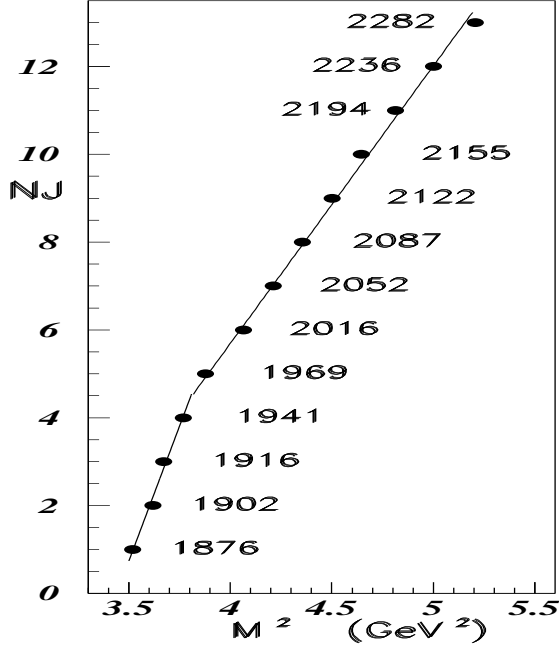


FIG. 18: Regge-like trajectory of all narrow structure dibaryonic masses observed in [20]. The two slope values are: $b=12.4 \text{ GeV}^{-2}$ and 6.3 GeV^{-2} .

isospins obtained by addition of $q\bar{q}$ clusters to $q\bar{q}$ for mesons and q^3 for baryons. It is therefore natural to compare the sequences of narrow mesonic and baryonic masses. The corresponding result is shown in fig. 19.

The left part of the fig. 19 shows the masses of the experimental narrow baryons above 1 GeV compared to the calculated masses obtained by addition of the nucleon mass to the masses of narrow experimental mesons. The absence of some baryonic masses may be related to their experimental non observation due to poorer resolution than the one got for low mesonic mass measurements. The overall correspondance is noteworthy. The dashed calculated mass uses the mesonic experimental value ($M=390 \text{ MeV}$), not extracted in previous papers, but extracted in this work - see section II.B. The right part shows in the mass range $1920 \leq M_{dib.} \leq 2300 \text{ MeV}$, the comparison between the experimental masses of narrow dibaryons and the masses obtained by addition of the nucleon mass to the narrow exotic baryonic masses. The dashed calculated mass, is obtained starting from an experimental mass $M=1210 \text{ MeV}$, not extracted from the first analyses, but extracted [21] in the reanalysis of the $\gamma p \rightarrow \pi^+ \pi^0 n$ reaction studied at MAMI [22] and the reanalysis of the $H(e, e' \pi^\pm) X$ electroproduction cross-section measured at JLAB Hall C [23].

B. Discussion

For all three species, the slope (in GeV^{-2}) decreases for increasing masses. All extracted slopes are larger (in

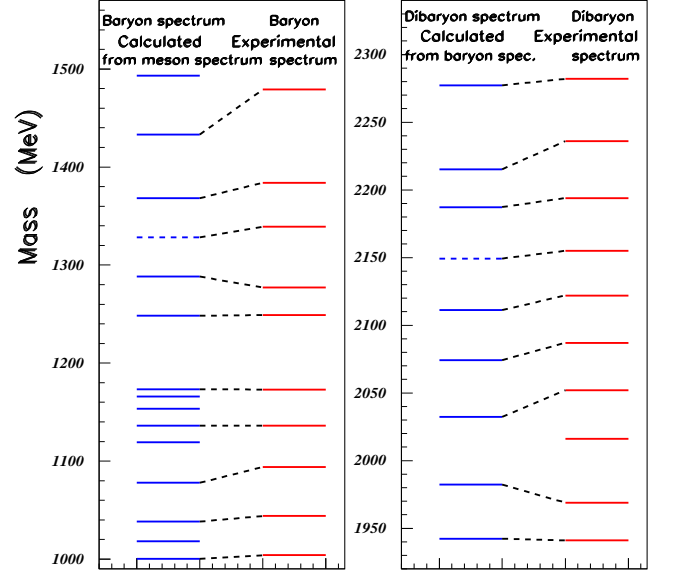


FIG. 19: In the left side, comparison between the exotic baryonic mass spectrum obtained using the mesonic exotic masses, and the experimental one. In the right side, comparison between the experimental narrow dibaryonic spectrum with the calculated one starting from the experimental baryonic narrow mass spectrum.

GeV^{-2}) than the slopes for "classical" PDG hadrons.

The importance of the concept of diquarks was often quoted in many papers. It was quantitatively discussed, on many examples of the PDG hadron spectroscopy by Sellem and Wilczek [24]. Mass formula [1] agrees with their statement "that the antisymmetric spin(isospin)-singlet state is more favorable energetically than the symmetric spin(isospin)-triplet state". Indeed, the calculated masses increase with spin (isospin). For baryons, the two first $(3/2, 3/2)$ calculated masses have $M=1200 \text{ MeV}$ and $M=1275 \text{ MeV}$. In [14] it was shown that "the broad PDG baryonic resonances are in fact collective states of several weakly excited and narrow resonances." Then the mean calculated mass value between $M=1200 \text{ MeV}$ and $M=1275 \text{ MeV}$ is at $\Delta M_c=299 \text{ MeV}$ from the nucleon mass, to compare to the experimental value: $\Delta M_c=290 \text{ MeV}$.

Following [24] good diquarks have spin 0 and isospin 0. We apply it for our diquark clusters for mesons, and observe that such condition is fulfilled for the calculated masses: $M=60 \text{ MeV}$, and is possible for $M=100 \text{ MeV}$, 180 MeV , and 220 MeV . All three unobserved masses at $M=120 \text{ MeV}$, 140 MeV , and 160 MeV , correspond to bad diquark cluster configurations (triplet spin (isospin) cluster state).

VI. CONCLUSION

$b \text{ (GeV}^{-2}\text{)}$	$q - q^2$	$q^3 - q\bar{q}$	$q^3 - (q\bar{q})^2$	M_{min}	M_{max}
100.4	292.8	168.6	119.2	939.6	957
62.6	369.7	213.5	150.9	957	1004
10.7	893.7	516	364.9	1004	1480
27.3	559.7	323.2	228.5	1480	1575
15.9	733.8	423.7	299.6	1575	1780

TABLE III: Constituent quark mass, for different clusters supposed to describe the baryonic narrow structures, derived from the Barut's equation [10]. M_{min} and M_{max} give, in MeV, the mass range of each trajectory.

In conclusion we have confirmed the existence of narrow structures in all three low mass hadronic species. The corresponding masses are reproduced with a small number of parameters, with help of a phenomenological mass relation [2]. These masses fit straight lines in Regge-like trajectories. This study stresses the importance of careful scrutiny of low mass hadronic spectroscopies.

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